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BULLETIN 385

CORNELL UNIVERSITY
AGRICULTURAL EXPERIMENT STATION

DUSTING AND SPRAYING NURSERY STOCK

VERN B. STEWART

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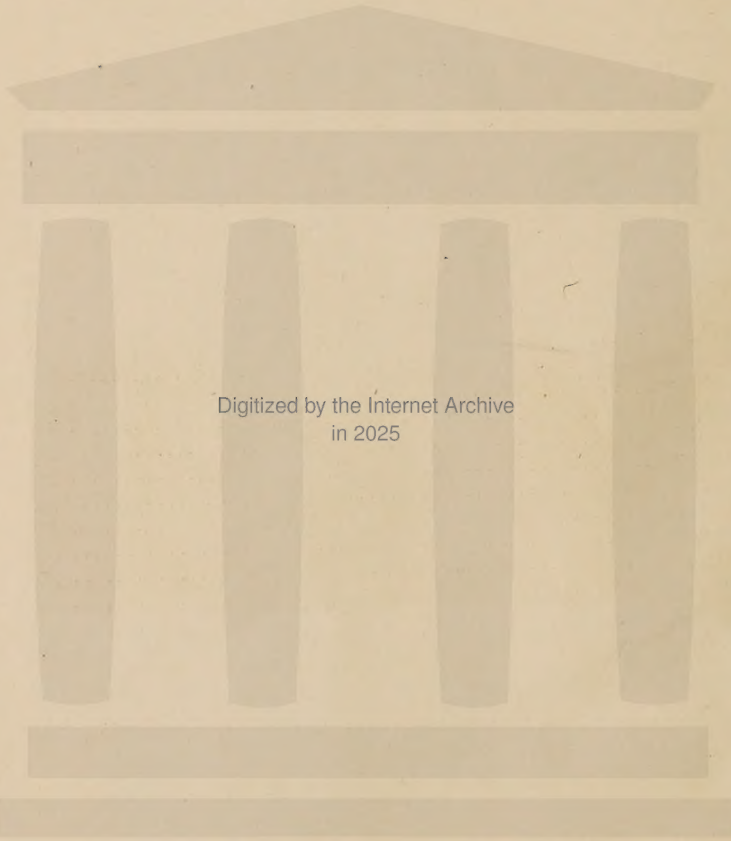
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DUSTING AND SPRAYING NURSERY STOCK

VERN B. STEWART

During the season of 1915 several experiments were conducted by the Department of Plant Pathology at Cornell University for the control of various leaf diseases of nursery stock.¹ The results obtained seemed to warrant further trials, and in 1916 the experimental work was continued on a more extensive scale. For the experiments in 1916 traction dusting machines (figs. 71 and 72) were used for applying the dust mixture, instead of the hand machine employed in 1915 (fig. 73). In most cases

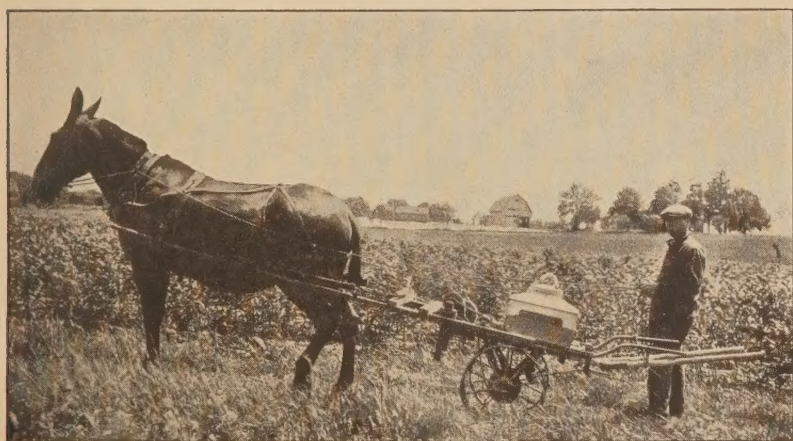


FIG. 71. A TRACTION DUSTER

The hopper of this machine holds about fifty pounds of dust mixture, which is discharged from the pipes in the rear. Photograph by R. E. Matheson

a half acre or more of stock was treated in order to thoroughly test the efficiency of the dust method. The dust mixture used for all experiments in 1916 was the same as that employed in 1915, namely, ninety parts of finely ground sulfur and ten parts of powdered arsenate of lead.²

In each experiment one or more small plats were treated with lime-sulfur solution to serve as a comparison with the dusted and the untreated plats. The lack of suitable spraying machinery made it necessary to apply the spray solution with a compressed-air hand sprayer; this was

¹ Stewart, V. B. Dusting nursery stock for the control of leaf diseases. Cornell Univ. Agr. Exp. Sta. Cir. 32:3-10. 1916.

² In all the experiments a finely ground flour sulfur, now known commercially as superfine sulfur, was used. This product is ground to such a fineness that at least 95 per cent will pass through a screen of 200 meshes to the inch. The arsenate of lead used was of the so-called fluffy type, the individual particles of which are much smaller than the majority of the particles of sulfur.

somewhat disadvantageous, since the pressure obtained with the hand sprayer was considerably less than that furnished by a traction or a power sprayer. Also it was necessary to limit the sprayed plats to a much smaller area than the dusted plats. On the other hand, in practically all cases the sprayed plats were large enough to determine the relative value of the dusting and the spraying method.

WEATHER CONDITIONS

Although the seasons of 1915 and 1916 were both exceptionally favorable for leaf diseases, there was considerable difference with respect to the occurrence of the various rainy periods.

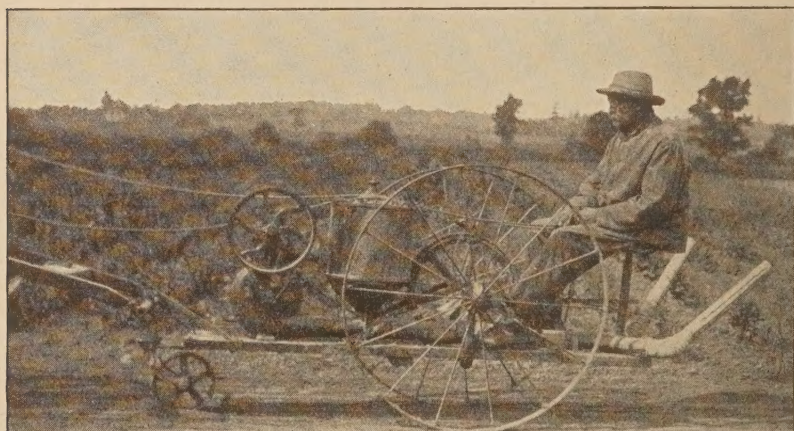


FIG. 72. A TRACTION DUSTING MACHINE

This machine is twenty-eight inches wide. The discharge pipes in the rear can be raised and lowered according to the height of the nursery stock. Large nursery trees, seven or more feet in height, can be thoroughly dusted. Photograph by C. R. Crosby

In 1915 there was very little precipitation previous to July 1 and the primary infection early in the spring was of little importance. Most foliage was relatively free from disease until after the prolonged infection period from June 30 to July 6. For the remainder of the summer, conditions were exceptionally favorable for leaf diseases and they appeared in great abundance.

In 1916 early infections were unusually severe owing to the excessive amount of precipitation accompanied by prolonged periods of damp, cloudy weather. During May and June leaf diseases appeared in great abundance and proved very destructive to all kinds of stock affected. Some plants suffered almost complete defoliation as early as July 1. After July 1 there was practically no rainfall until August 11 and 12,

when an infection occurred which caused considerable loss of foliage. In some cases the effect of the defoliation in midsummer was very severe. The growth of the plants was completely checked until after the rainfall late in August, when the precipitation prompted a new growth and many of the plants developed clusters of small new leaves at the tips of the shoots. This late growth delayed proper maturation of the plants in the autumn and made them more susceptible to winter injury.



FIG. 73. A HAND DUSTING MACHINE

This machine is suitable for treating small plantings of nursery stock

ARRANGEMENT OF EXPERIMENTAL PLATS

Since a complete report of the results obtained in 1915 has not been recorded, a somewhat detailed account is included in this publication of experiments for both 1915 and 1916.

The location of the experimental plats frequently has an important bearing on the results. There is always danger that the dust mixture may be carried by the wind to the other plats, and this difficulty makes it impossible to select trees in adjoining rows for different kinds of treat-

ment when a dust mixture is used. For most of the experiments performed, the plats were arranged so that a part of each row of plants was included in each of the different plats. With such an arrangement there is less danger that the dust mixture may affect the results in the sprayed and the untreated plats. On the other hand, this plan is objectionable since there may be a lack of uniformity in the plats with respect to soil conditions and other factors that influence the growth of the plants. Often trees in the same row show a marked difference in size. These conditions make it impossible to compare the experimental plats by determining the caliper and height measurements of the individual plants. Therefore, since the growth of nursery stock is seriously affected by the loss of foliage during the growing season, the amount of premature defoliation was the principal factor considered in determining the damage caused by the leaf diseases. The loss of foliage tends to check the growth of the plant, and thus influences the caliper and height measurements.

Experiments were performed for the control of leaf diseases of horse-chestnut, currant, plum, cherry, quince, apple, and rose.

LEAF BLOTCH OF HORSE-CHESTNUT³

In 1915 a single row of large four-years-old horse-chestnut trees was selected for the experiment on leaf blotch, and the same trees were again used for an experiment in 1916. In both seasons the trees in the first 150 feet of the row were treated with the dust mixture; those in the next 50 feet were left untreated; those in the next 100 feet were sprayed with lime-sulfur solution; and those in the last 75 feet were left untreated.

Experiment in 1915

In 1915 the first application of dust and spray was made on May 11, when all the buds had opened and some of the leaves were well developed. Subsequent applications were made on May 25, June 7, June 21, July 9, and August 2. Lime-sulfur solution diluted one to fifty was used for treating the sprayed plat. In the attempt to thoroughly cover all parts of the foliage by means of a hand sprayer, many of the leaves were drenched with the spray liquid and considerable injury resulted.

A comparison of the trees in the different plats was obtained by determining the percentage of affected leaflets on each tree. Many leaf pathogenes cause severe defoliation, but usually most of the horse-chestnut leaves affected with the leaf blotch disease remain on the tree. However, on smaller trees, especially seedlings, considerable defoliation may occur. When severely affected the foliage has the appearance of having been burned over by fire.

³ The leaf blotch disease of horse-chestnut is caused by the fungus *Guignardia Aesculi* (Peck) Stewart.

The number of trees of which records were taken, the total number of leaflets, and the number and mean percentage of infected leaflets for the trees in the different plats, are shown in table 1. Approximately sixty per cent of the foliage on the untreated trees showed infections of

TABLE 1. DUSTING AND SPRAYING EXPERIMENT WITH HORSE-CHESTNUT TREES IN 1915

Treatment	Number of trees	Total number of leaflets	Affected leaflets	
			Number	Mean percentage
Untreated.....	55	7,980	4,737	59.08 $\pm$ 2.61
Lime-sulfur solution 1 to 50.....	61	7,385	762	11.78 $\pm$ 0.95
Sulfur 90, arsenate of lead 10.....	72	9,735	310	3.11 $\pm$ 0.20

the leaf blotch disease, while only three per cent of the foliage was diseased on the dusted trees. The dense foliage on the trees hindered the proper distribution of the lime-sulfur spray over all the leaves, and this, no doubt, reduced somewhat the effectiveness of the spray solution. About twelve per cent of the foliage on the sprayed trees was diseased.

Experiment in 1916

The experiment for the control of leaf blotch of horse-chestnut was repeated in 1916, using the same row of trees as in 1915. Owing to the foliage injury caused by the lime-sulfur solution the previous year, the solution used in 1916 was diluted one gallon to sixty gallons of water.

The first application was made in the forenoon of May 15, between showers of a rain period which began in the afternoon of May 14 and continued until May 17. At this time most of the leaves on the trees were about two-thirds developed and during the rainy weather a severe ascospore infection occurred. Other applications were made on May 29, June 13, July 5, and July 25. When final observations were made on September 11, the untreated trees had the appearance of having been burned over by fire, practically all the leaves being affected. Considerable disease was also apparent on the sprayed trees.

The results of the experiment are given in tables 2 and 3.⁴ Approximately ninety-nine per cent of the untreated foliage was diseased as

⁴ Complete data of the records taken in the untreated and in the dusted horse-chestnut plats for the experiment conducted in 1916 are given in table 2. The total number of leaflets for each tree was recorded, along with the number of diseased leaflets, and from these figures the percentage of infected leaflets for each tree was determined. The percentage column shows the variation in amount of diseased leaflets

TABLE 2. COMPLETE DATA OF RECORDS FOR UNTREATED AND DUSTED HORSE-CHESTNUT TREES FOR EXPERIMENT IN 1916

Treatment	Total number of leaflets	Affected leaflets		Treatment	Total number of leaflets	Affected leaflets	
		Number	Percentage			Number	Percentage
Untreated	440	440	100.00	Sulphur 90, arsenate of lead 10	185	10	5.40
	255	250	98.04		350	35	10.00
	205	205	100.00		475	100	21.05
	475	475	100.00		260	28	10.77
	400	400	100.00		645	30	4.65
	260	260	100.00		110	15	13.64
	630	624	99.05		570	25	4.38
	480	480	100.00		275	30	10.91
	610	593	97.21		700	40	5.71
	30	30	100.00		390	15	3.85
	355	355	100.00		300	42	14.00
	285	285	100.00		445	34	7.64
	450	448	99.55		475	39	8.21
	360	354	98.33		560	43	7.68
	425	418	98.35		280	24	8.57
	505	505	100.00		215	29	13.49
	180	172	95.55		480	40	8.33
	215	215	100.00		510	34	6.67
	375	365	97.33		310	41	13.22
	545	545	100.00		220	2	0.91
	525	525	100.00		360	32	8.89
					105	8	7.62
					240	22	9.17
					305	28	9.18
					440	36	8.18
Total.....	8,005	7,944	2,083.41	Total.....	9,205	782	222.12
Mean.....			99.21 ± 0.19	Mean.....			8.88 ± 0.50

compared with about nine per cent for the dusted trees. The failure of the lime-sulfur solution to protect the trees, which showed about fifty-five per cent of the leaves affected, is attributed in part to the use of a hand sprayer. It was difficult to thoroughly cover all of the dense foliage without drenching the leaves. Furthermore, diluting the lime-sulfur solution one to sixty reduced somewhat the fungicidal value of the spray solution. The relatively high percentage of diseased leaves on dusted trees, as compared to those dusted in 1915, is due chiefly to the infection that occurred during the night of May 14. There was a period of damp, cloudy weather of about eighteen hours duration before the first application was made. This apparently was sufficient time for the discharge of some of the ascospores of the fungus from the old leaves on the ground, and for these ascospores to produce infections on the new foliage before the fungicides were applied.

TABLE 3. DUSTING AND SPRAYING EXPERIMENT WITH HORSE-CHESTNUT TREES IN 1916

Treatment	Number of trees	Total number of leaflets	Affected leaflets	
			Number	Mean percentage
Untreated.....	21	8,005	7,944	99.21 $\pm$ 0.19
Lime-sulfur solution 1 to 60.....	25	9,375	5,212	54.61 $\pm$ 1.34
Sulfur 90, arsenate of lead 10....	25	9,205	782	8.88 $\pm$ 0.50

The importance of the infection period of May 14 to May 17 is seen by the results of an experiment in another planting of horse-chestnut trees. Owing to the rainy weather it was necessary to delay the first application until May 26. During the prolonged period of infection from May 14 to May 17 before the trees were treated, a large percentage of the foliage became infected. The application made on May 26 was too late to prevent any of the primary infection, and since horse-chestnut

for each tree. The probable error of the mean percentage was determined by means of Peter's formula, $\pm 0.8453 \frac{\sum v}{n\sqrt{n-1}}$, in which v equals the difference between the mean and the percentage of infected leaflets for each tree, and n equals the number of trees from which records were taken. In all the experiments the probable error of the mean percentage was determined by means of Peter's formula,

except for the experiments with currants, in which case Bessel's formula, $\pm 0.6745 \sqrt{\frac{\sum d^2}{n(n-1)}}$, was used. In this formula d is the difference between the mean and each individual observation, and n is the number of observations.

trees make but little secondary growth the experiment was abandoned. When observed on July 10 there was very little green foliage on any of the trees in the block. The failure to control the leaf blotch in these trees emphasizes the absolute necessity of making the applications before periods favorable for infection, so that the foliage may be protected. Otherwise such applications have little value.

The results of the experiments for the control of leaf blotch of horse-chestnut indicate that dusting is preferable to spraying. There is no question but that the lime-sulfur solution greatly reduced the amount of disease. On the other hand, it was not so effective as the dust mixture, and furthermore the spray liquid is more difficult to apply. In treating three- to five-years-old horse-chestnut trees in the nursery, the work can be done much better and more easily by means of the dusting method, at a cost which is little, if any, greater than that for the spraying method.

LEAF SPOTS OF CURRANT⁵

Experiment in 1915

The experiment performed in 1915 for the control of the leaf spots of currant included a number of rows, about 70 feet in length, of second-year Cherry currant bushes. Rows 1 to 6 were dusted; row 7 served as a buffer row and was not treated; rows 8, 9, 10, and 11 were sprayed with lime-sulfur solution diluted one to fifty; rows 12, 13, 14, 15, 16, and 17 were left untreated. The first application was made on May 10, soon after the leaf buds had opened. Subsequent applications were made on May 25, June 7, June 21, July 9, July 19, and August 2. Final data on the experiment were recorded on September 3, when a large part of the foliage on the untreated bushes had already fallen.

It is difficult to determine accurately the amount of damage caused by the leaf spots on currant bushes. A determination of the number of leaves infected is not a suitable method, since the presence of one or two small lesions on a leaf may not seriously affect it. On the other hand, if infection occurs on the petiole the leaf usually drops prematurely. Also many of the smaller leaves develop in a cluster, making it practically impossible to count the leaf scars of foliage missing and thus determine the number of leaves that were originally present on the bush. Since in each experiment the leaf spots caused severe premature defoliation in the untreated plats, comparisons were made of the bushes in the different plats by counting the number of leaves that remained on the bushes throughout the season. No insect pests were present and the amount

⁵ The leaf spot disease caused by *Mycosphaella grossulariae* (Fr.) Lind., and the anthracnose caused by *Pseudopeziza ribis* Kleb., are commonly found on currant nursery stock in New York State.

of defoliation caused by agents other than the leaf spot fungi is considered negligible.

The results of the experiment are given in table 4. The bushes in the different plats averaged about the same in size. However, as is to be noted in table 4 under *Remarks*, there was a great variation in number of leaves for individual bushes in each plat. There was very little premature defoliation of the bushes in the sprayed and the dusted plats. Most of the leaves remained on the bushes throughout the summer. At the end of the growing season there was an average of twenty-seven leaves per bush on the untreated bushes, as compared with an average of over eighty leaves on each bush in the treated plats.

TABLE 4. DUSTING AND SPRAYING EXPERIMENT WITH CURRANT BUSHES IN 1915

Treatment	Number of bushes	Total number of leaves	Average number of leaves per bush	Remarks
Untreated (Rows 14 and 15)	137	3,722	27.17 ± 1.36	Number of leaves per bush varied from 0 to 71
Lime-sulfur solution 1 to 50 (Row 9)	72	6,039	83.87 ± 4.04	Number of leaves per bush varied from 15 to 275
Sulfur 90, arsenate of lead 10 (Row 3)	74	6,328	85.51 ± 3.61	Number of leaves per bush varied from 4 to 183

Experiment in 1916

An experiment for the control of the leaf spots of currant was conducted in 1916, using a traction duster for applying the dust mixture. A number of rows of the White Grape variety in a block of currants were selected for the experiment. The rows were about 500 feet in length and extended north and south. Starting at the northeast corner, the bushes in the first 100 feet of twelve rows were sprayed with lime-sulfur solution 1 to 40; the bushes in the remaining 400 feet of nine of these rows on the east side were dusted with sulfur 90 parts and arsenate of lead 10 parts; eight rows extending the entire length of the block and adjoining the sprayed plat were left untreated for a check.

The first application was made on May 15, during an intermission in the rain period which lasted from May 14 until May 17. The first new leaves on the canes were about half developed when the bushes were treated. Apparently this application was made in time to prevent considerable primary infection, since there were but few infected leaves on the treated bushes when another application was made on May 29. The untreated bushes showed numerous diseased leaves on that date. Subsequent applications were made on June 13 and June 22, and then, because of the prolonged dry weather, the plats were not treated again until July 25. At that time the untreated bushes were almost completely defoliated, while very little of the foliage was missing from the dusted and the sprayed bushes. It would have been desirable to have made another application just previous to August 11, after which time there were several infection periods, but the delay in receiving repairs for a French dusting machine prevented further treatments for the season. When results of the experiment were recorded some of the leaves showed new leaf spot lesions, due to infections that occurred after August 11.

TABLE 5. SPRAYING AND DUSTING EXPERIMENT WITH CURRANT BUSHES IN 1916

Treatment	Number of bushes	Total number of leaves	Average number of leaves per bush	Remarks
Untreated	110	1,566	14.24 ± 0.95	Number of leaves per bush varied from 0 to 65
Lime-sulfur solution 1 to 40	56	5,393	96.30 ± 3.87	Number of leaves per bush varied from 7 to 171
Sulfur 90, arsenate of lead 10	56	5,656	101.00 ± 3.98	Number of leaves per bush varied from 21 to 242

As in the experiment in 1915, a comparison was obtained by counting the leaves present on individual bushes in the middle row of each plat. The average number of leaves on each bush in the dusted and the sprayed plats was approximately the same (table 5). Both fungicides were effective in preventing the attacks of the parasites which cause the leaf spot diseases. There was an average of about fourteen leaves on each bush in the untreated plat as compared with one hundred and one leaves on each bush in the dusted plat. The great variation in the number of

leaves on each bush as indicated in table 5 is due to the differences in size of the individual bushes rather than to the results of premature defoliation.

LEAF SPOT OF PLUM⁶

There is a considerable difference in the susceptibility of the varieties of plum trees to the leaf spot, or shot-hole disease, which was unusually common in 1916. In the nursery the European varieties are severely affected and often complete defoliation of the trees occurs in midsummer. The Japanese varieties are not so susceptible (fig. 74). No experiments were performed for the control of this disease in 1915.

Experiment in 1916

Two rows of two-years-old European plum trees of the variety German Prune were selected for the experiment in 1916. The trees comprised the last two rows of a large block of plum trees of several varieties. Starting at the north end, the trees in the first 150 feet of the two rows were sprayed with lime-sulfur solution diluted one to fifty; those in the next 200 feet were left untreated; those in the next 500 feet were dusted with the 90-10 mixture of finely ground sulfur and powdered arsenate of lead; those in the last 300 feet were left untreated.

The first application was made on May 26, when the first leaves were about half developed. The next three applications were made on June 12, June 23, and July 6. During this time there were numerous infection periods and on July 6 considerable leaf spot was present on the untreated trees. Subsequent applications were made on July 20 and August 9. On the latter date the



FIG. 74. VARIETAL SUSCEPTIBILITY OF PLUM TREES TO THE LEAF SPOT DISEASE

The trees on the right are of the European variety German Prune, and were defoliated by the leaf spot disease. The trees on the left are of the Japanese variety Wickson, and were not affected by the disease. Photographed September 14, 1916

⁶ The plum leaf spot, or shot-hole disease, is caused by the fungus *Coccomyces prunophoræ* Higgins.

untreated trees were practically defoliated and none of the leaves remaining on the trees were free from disease, while the sprayed and the dusted trees showed only a few infected leaves and almost no defoliation (fig. 75).

Final data on the experiment were recorded on September 14. Since on young branches of defoliated plum trees there is a well-defined scar where each leaf was attached, it was possible to count the number of leaf scars along with the leaves present and thereby estimate the number of leaves that were originally on the tree. The number of trees in each plat from which data were recorded, the estimated total number of leaves



FIG. 75. DUSTED AND UNTREATED TWO-YEARS-OLD PLUM TREES OF THE VARIETY GERMAN PRUNE

The defoliated trees in the foreground were not treated; the trees in the distance were dusted and premature defoliation was prevented. Photograph by C. R. Crosby, August 9, 1916

originally on the trees, the number of leaves present, and the number of leaves missing, are given in table 6. All records were taken from trees in the same row, and in each plat these trees were determined by selecting every fifth tree in the row. More than ninety-five per cent of the foliage remained on the treated trees throughout the season, as compared with less than twenty per cent on the untreated trees, which lost a large portion of their leaves early in the summer.

On September 14 the untreated trees showed a larger percentage of non-infected foliage than when observed on August 9. This is accounted

TABLE 6. DUSTING AND SPRAYING EXPERIMENT WITH EUROPEAN PLUM TREES IN 1916

Treatment	Number of trees from which data were recorded	Total number of leaves originally on trees	Non-infected leaves present		Diseased leaves present		Leaves missing	
			Number	Mean percentage	Number	Mean percentage	Number	Mean percentage
Untreated	50	10,289	681	6.10 ± 0.74	1,015	10.40 ± 0.66	8,593	83.51 ± 0.95
Sulfur 90, arsenate of lead 10....	45	7,234	6,856	94.72 ± 0.34	341	4.84 ± 0.31	37	0.45 ± 0.08
Lime-sulfur solution 1 to 50....	45	7,235	6,940	95.85 ± 0.36	266	3.77 ± 0.31	29	0.37 ± 0.10

for by the fact that defoliation occurred early in the summer, and after the heavy rainfall in late August the trees began growing again. This late growth resulted in the development of new foliage, which in all cases was in the form of clusters of very small leaves at the tips of the shoots. Without question the development of the new leaves at this time was a detriment to the trees, since the late growth retarded proper maturation, making the trees more susceptible to winterkilling.

LEAF SPOT OF CHERRY ⁷

Experiment in 1915

An experiment in 1915 for the control of leaf spot of cherry included four rows of first-year Tartarian cherry trees. The trees in the first 100 feet of the four rows were treated with the mixture of sulfur and powdered arsenate of lead; those in the next 125 feet were left untreated; those in the last 100 feet were sprayed with lime-sulfur solution diluted one to fifty. The first application of dust and spray was made on May 11, when the trees were about six inches high. Subsequent applications were made on May 25, June 7, June 27, July 9, July 19, and August 2.

TABLE 7. DUSTING AND SPRAYING EXPERIMENT WITH SWEET CHERRY TREES IN 1915

Treatment	Number of trees	Total number of leaves originally on trees	Leaves missing	
			Number	Mean percentage
Untreated.....	50	2,094	714	35.60 $\pm$ 0.94
Lime-sulfur solution 1 to 50.....	82	3,133	580	20.26 $\pm$ 0.77
Sulfur 90, arsenate of lead 10.....	84	3,539	292	9.64 $\pm$ 0.44

The young trees made a very rapid growth, and owing to the heavy rainfall and numerous infection periods it was difficult to make the applications so that the new foliage was protected at all times. Many infections occurred in all the plats, but the trees in the treated plats were not so severely infected as were the untreated trees.

The results of the experiment were recorded on August 31, all records being taken from trees in the third row, a part of which was in each of the different plats. The percentage of premature defoliation caused by the leaf spot disease was determined by counting the number of leaf

⁷ The cherry leaf spot, or yellow-leaf disease, is caused by the fungus *Coccomyces hiemalis* Higgins.

scars on each tree where leaves were missing. The number of trees in each plat of which records were made is given in table 7, also the total number of leaves originally on the trees (determined by counting the leaves present plus the leaf scars due to defoliation), and the number and mean percentage of leaves missing.

In this experiment the lime-sulfur solution was not so effective as the dust mixture. This failure may be attributed, in part at least, to the location of the different plats. The sprayed trees were on lower land, where the soil remained saturated with water for a considerable length of time after periods of heavy rainfall. Not only did the excess of water affect the growth of the trees in that area, but also the moist conditions were more favorable for the leaf spot disease. This situation made a comparison of caliper and height measurements for trees in different plats of no value. Undoubtedly the defoliation would not have been so great on the sprayed trees if they had been in rows adjoining the dusted plat, which was on a gentle slope of land conducive to proper drainage.

Not only was there a higher proportion of premature defoliation on the untreated trees, but also the leaves that remained were more severely affected than those remaining on the treated trees, many of them turning yellow and being of little value to the trees. On the other hand, most of the foliage on the sprayed and the dusted trees showed only a few infections, and was still green when observed for the last time on September 11.

Experiment in 1916

Another experiment was conducted in 1916 for the control of the leaf spot disease of cherries, but unfortunately this experiment also failed

TABLE 8. DUSTING EXPERIMENT WITH TWO-YEARS-OLD TARTARIAN CHERRY TREES IN 1916

Treatment	Number of trees	Total number of leaves originally on trees	Leaves missing	
			Number	Mean percentage
Untreated.....	20	2,629	1,801	68.23 $\pm$ 1.48
Sulfur 90, arsenate of lead 10....	19	2,818	478	16.77 $\pm$ 0.60

to prove entirely satisfactory. The location of the different plats was again a factor influencing the results. The experiment as originally

planned consisted of seven rows of two-years-old Tartarian cherry trees. There were five experimental plats, so arranged that a part of each row of trees was included in each plat. Poor drainage, along with injury by freezing which had occurred during the winter months, affected the growth of the trees to such an extent that early in the summer the experiment, except for one dusted plat and an adjoining untreated plat, was abandoned.

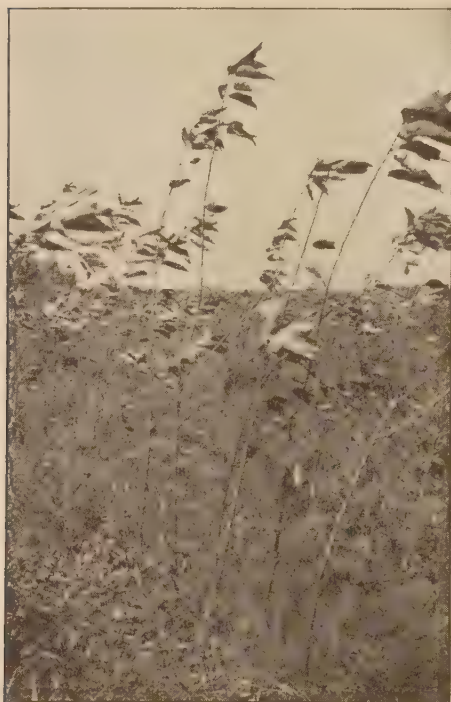


FIG. 76. TWO-YEARS-OLD SWEET CHERRY TREES DEFOLIATED BY THE LEAF SPOT DISEASE

Many of these trees failed to make sufficient growth to be graded as first-class stock. Photographed September 11, 1916

The first application was made on May 15, when the first leaves were about one-third developed. Subsequent applications were made on May 29, June 13, June 22, July 5, and July 25. On June 10 a heavy precipitation occurred, followed by damp, cloudy weather for a period of twenty-four hours. At this time the trees were growing very rapidly and had made considerable new growth since the last treatment on May 29. The weather conditions of June 10 and 11 were favorable for the leaf spot disease, and many infections occurred on the new unprotected foliage in both plats. No treatments were made after July 25, owing to the delay in receiving repairs for the French dusting machine which was in use at this nursery.

When final data on this experiment were recorded (table 8), lesions of the leaf spot disease were apparent on all the trees, but the untreated trees were more severely affected than those in the dusted plat. Not only was the defoliation greater on the untreated trees, but the foliage that remained was turning yellow and was of little value to the trees (fig. 76). A comparison was made of the trees in the fourth row of each plat. The amount of defoliation was determined by counting the leaf scars on the trees where leaves were missing. The figures in the third column of table 8 indicate the number

of leaves that remained on the trees in addition to those lost by premature defoliation. Approximately seventeen per cent of the leaves in the dusted plat were lost prematurely, as compared with sixty-eight per cent for the untreated trees.

LEAF SPOT OF QUINCE⁸

No experiments were conducted in 1915 for the control of the quince leaf spot.

Experiment in 1916

An entire block consisting of eight rows of two-years-old quince trees was used in the experiment in 1916. There were several varieties of quince trees in the block, and the rows, which were about 1100 feet in length, were divided into six experimental plats, a part of each row being included in each plat. Starting at the north end, the trees in plat 1, 100 feet long, were sprayed with lime-sulfur solution one to fifty; plat 2, 100 feet long, was left untreated; plat 3, about 600 feet long, was dusted with the mixture of sulfur and arsenate of lead; plat 4, 100 feet long, was sprayed with lime-sulfur solution; plat 5, 100 feet long, was not treated; and plat 6, about 200 feet long, was dusted (fig. 77).

An attempt was made to give the trees the first treatment previous to the infection period of May 14 to May 17, but weather conditions made it necessary to delay this first application until May 26. On that date the first cluster of new leaves was well developed and the delay in making the first application had permitted considerable infection to occur. These infections were apparent when the second application was made, on June 12. Subsequent treatments were given on June 23, July 6, July 20, and August 9. On July 20 the affected leaves were more numerous on the untreated trees than on those that were dusted or sprayed. This condition was especially noticeable when the trees were examined again on August 9.

Final data on the experiment were recorded on September 19, all records being made from trees in the sixth row. These trees were of the variety Rea's Mammoth, and appeared to be slightly more susceptible to the leaf spot disease than did any of the other varieties. Twenty trees in each of plats 3, 4, and 5 were selected for determining the results of the experiment. In the dusted plat a record was taken of every twentieth tree in the row, and in the other two plats every fifth tree in the row was selected.

The approximate number of leaves originally on each tree was determined by counting the leaves present and the leaf scars where leaves were missing. A tabulation is given in table 9 of the total number of

⁸ The leaf spot disease of quince is caused by the fungus *Fabrea maculata* (Lév.) Atk.



FIG. 77. DUSTING TWO-YEARS-OLD QUINCE TREES

The dust mixture floats like smoke through several rows of trees, completely covering the foliage. Photograph by C. R. Crosby

TABLE 9. DUSTING AND SPRAYING EXPERIMENT WITH QUINCE TREES IN 1916

Treatment	Number of trees from which data were recorded	Total number of leaves originally on trees	Non-infected leaves present		Diseased leaves present		Leaves missing	
			Number	Mean percentage	Number	Mean percentage	Number	Mean percentage
Untreated.	20	3,579	21	0.66 ± 0.17	2,091	58.65 ± 2.07	1,467	40.68 ± 2.13
Sulfur 90, powdered arsenate of lead 10.	20	3,451	2,565	74.28 ± 1.44	619	18.05 ± 1.09	267	7.66 ± 0.89
Lime-sulfur solution 1 to 50.	20	3,215	2,226	69.39 ± 1.82	735	22.52 ± 1.60	254	8.07 ± 0.71

leaves originally on the trees, and the number and mean percentage of leaves not infected, of diseased leaves, and of leaves lost by premature defoliation.

The relatively high percentage of diseased leaves, and also of defoliation, on the trees in the treated plats is attributed principally to the infections that occurred during the period from May 14 to May 17, before the first application was made. Very little of the foliage that developed subsequently was affected. Practically all of the leaves remaining on the untreated trees were diseased, and it was very apparent that the number of infections on each leaf was much smaller on the treated trees. Approximately forty per cent of the foliage was missing from the untreated trees, as compared with seven per cent on the dusted trees.

SCAB DISEASE OF APPLE⁹

For several years the apple scab disease has been very destructive on certain varieties of apples in some of the nurseries of New York State and considerable damage has resulted from premature defoliation of the affected trees. The varieties of apples most commonly attacked by the scab fungus are Transcendent, Martha, and McIntosh, although the disease usually may be found to some extent on all varieties. On McIntosh trees, particularly, the fungus often attacks also the twigs and the branches, causing lesions which, along with premature defoliation, check the growth of the trees.

In 1916 several rows of two-years-old McIntosh trees in a nursery were so severely affected by the scab disease that only a small proportion of them made sufficient growth to be graded as first-class stock. Generally two- and three-years-old trees are more severely affected, but usually enough infections occur in the first-year-apple buds to enable the fungus to become established in the block. The diseased leaves fall to the ground, where they remain as a source of inoculum for the new foliage that develops the next year, and if weather conditions are favorable the scab disease appears in great abundance early in the season. The difference in varietal susceptibility to the scab disease is shown in figure 78. The trees on the left are of the variety Excelsior and have lost practically none of their foliage, while the Martha trees in adjoining rows show a large amount of defoliation.

No experiments were conducted in 1915 for the control of the scab disease on apple nursery stock.

Experiment in 1916

On May 26, 1916, attention was called to several rows of three-years-old Martha apple trees which were severely affected with the scab disease.

⁹ The scab disease of apple is caused by *Venturia inaequalis* (Cke.) Wint.

Primary infection by the apple scab fungus had occurred during the rain period of May 14 to May 17, and it was impossible to find a single leaf that was not diseased. In anticipation that the trees would make more new growth, an experiment was planned to protect the new foliage that would develop subsequently. The rows of trees were divided into three experimental plats. Plat 1 was treated with lime-sulfur solution diluted one to fifty; plat 2 was not treated; plat 3 was dusted with the mixture of sulfur and powdered arsenate of lead.

Applications were made on May 26, June 12, June 23, and July 6. After the application of July 6 the experiment was abandoned, owing to the fact that the trees failed to develop new foliage after the infection in May. No data were obtained as to the effectiveness of the spray liquid and the dust mixture in preventing the scab disease. On the other hand, when the trees were observed on October 2 for the last time it was not difficult to distinguish between the treated and the untreated trees. The untreated trees were almost completely defoliated, while not only more foliage remained on the treated trees but also the leaves were less severely affected. Apparently the fungicides prevented considerable secondary infection on the



FIG. 78. VARIETAL SUSCEPTIBILITY OF APPLE TREES TO THE SCAB DISEASE

The defoliated trees on the right are of the variety Martha; those on the left are of the variety Excelsior. Although of the same age the defoliated Martha trees made less growth and were smaller than the Excelsior trees, which were not affected by the scab disease. Photographed September 14, 1916

foliage that was already diseased. Undoubtedly an application of the fungicides before May 14 would have been effective in preventing a large part of the primary infection. The results of the experiment performed emphasize again the importance of making the applications at the opportune time. In this case the trees were so severely damaged early in the season that they failed to recover sufficiently to develop new leaves and continue growing throughout the summer. The defoliated Martha trees illustrated in figure 78 are of the same age as,

but much smaller than, the Excelsior trees, which were not affected by the scab disease.

MILDEW OF ROSE ¹⁰

Experiment in 1915

In 1915 an experiment was conducted for the control of the powdery mildew fungus on large Crimson Rambler rosebushes. The bushes were planted thickly and formed an arbor several hundred feet in length. A number of these bushes were dusted with the mixture of sulfur and powdered arsenate of lead by means of a hand duster, the first application being made on June 18, just as the mildew began to appear. Subsequent applications were made on July 12, July 21, and August 5. The



FIG. 79. DUSTING ROSES

This machine was used also for dusting the large horse-chestnut trees shown in the distance

applications of the dust mixture prevented the attacks of the mildew fungus throughout the growing season, and the bushes retained their beauty and appeared green and healthy until late in the autumn. The untreated bushes were severely affected by the mildew, and by midsummer many of the leaves and shoots were dried out and killed by the fungus.

Experiment in 1916

The same rose arbor was dusted again in 1916, on a more extensive scale, the dust mixture being applied by a traction machine (fig. 77). About 100 feet of the arbor was left untreated for a check. The first application was made on July 6 and subsequent treatments were given on July 20

¹⁰ The mildew of roses is caused by *Sphaerotheca pannosa* (Wallr.) Lévl. var. *rosæ* Wor.

and August 9. Although another application later in the season would have been desirable, the dusted bushes were only slightly affected, while the mildew had caused considerable injury on the untreated bushes when they were observed for the last time on October 2. It is to be noted also that there was much less defoliation caused by the black spot fungus on the treated bushes than on those that were not dusted.

GENERALIZATIONS

The results of the experiments for the two years indicate that the dusting method is the more satisfactory means of treating nursery plantings for the control of leaf diseases. Where there has been a comparison of dusted plants and sprayed plants, the dust mixture has proved as effective as, and in most cases slightly more effective than, the lime-sulfur solution. This is particularly true for the leaf diseases of horse-chestnut and quince trees.

In certain experiments satisfactory control results were not obtained. These failures, however, can be attributed to causes such as failure to make the applications at the proper time, rather than to a lack of effectiveness on the part of the dust mixture. Furthermore, in each case in which the dust mixture did not control the disease the lime-sulfur solution also failed. Apparently, good control results may be expected if the applications are made so as to protect as much as possible of the foliage throughout the growing season.

Materials to be used

In all the experiments conducted in the nursery, a dust mixture was used consisting of ninety parts of finely ground sulfur and ten parts of powdered arsenate of lead. The arsenate of lead was added, not only for its value as an insecticide against chewing insects, but also, and primarily, for its adhesive properties. When lead arsenate is moistened there is a tendency for it to become somewhat gelatinous and sticky, thus increasing the adhesiveness and spreading quality of the mixture. The dust mixture is considerably more expensive than the lime-sulfur solution. On the other hand, the actual total expense for the dusting method is but slightly greater than for the liquid, since the handling of a large bulk of water is eliminated, the outfit as compared with a power sprayer is less expensive, and the operators are fewer in number. But, above all, the increased cost of the dust mixture is largely offset by the great saving in time, and especially by the ability to cover large areas at critical periods in a minimum of time. Only one man and a horse are necessary to operate the dusting machine, which runs between the rows and thoroughly dusts four rows of stock of any height found in the nursery (figs. 77 and 79). In some plantings, such as currants, the number of rows treated

at one time often may be increased to six or seven. There is practically no delay in refilling the hopper, and the horse should walk at a rapid gait in order that there be no waste of the dust mixture.

Cost of the dust and spray methods

In the block of quince trees (page 353), which consisted of eight rows, four rows were thoroughly dusted at one time. Considering the time required for the horse with the machine to walk the distance of the block and return, only fifteen minutes were necessary to dust the entire area of two-thirds of an acre. Thirty-five pounds of dust mixture was used in covering the eight rows. The cost of the dust mixture for one application was \$1.90; and with 15 cents added for labor, the entire block could be dusted within fifteen minutes at an estimated cost of \$2.05, equivalent to about \$3 an acre.

Judging from the time required to spray the quince experimental plats with hand machines, it would have taken one man eight hours to thoroughly spray the entire block of trees. Figuring the cost of the spray solution plus the cartage of water at 35 cents, and estimating the cost of eight hours labor at \$1.60, one application of spray solution could be made for \$1.95.

The slight increase in cost of the dusting method is of little importance considering the fact that the work can be done so much more quickly and thoroughly as compared with the spraying method. The ability to cover large areas in a minimum length of time is of primary importance when making the applications just previous to periods of weather favorable for infection of the leaf spot diseases.

A suitable spraying outfit would no doubt reduce somewhat the cost of spraying and afford a means of covering certain stock more rapidly than by hand sprayers. On the other hand, there are on the market no power spraying machines that can be used to advantage in treating plantings of nursery stock varying from one to seven or more feet in height. Furthermore, the labor required to operate a power sprayer is a special item. During the rush of other work in the nursery there is often a tendency to delay spraying until it is too late for the application to be effective. This difficulty is largely overcome with the dusting method, since the dusting can be done more quickly and with less labor, making it unnecessary to sacrifice other nursery work.

The ten-per-cent addition of powdered arsenate of lead to the finely ground sulfur greatly increases the cost of the dust mixture, and it is believed that the amount of arsenate of lead could be materially reduced without decreasing the effectiveness of the mixture. On the other hand, the addition of arsenate of lead is often desirable for certain applications

when treating stock infested with chewing insects, such as rose and currant worms, and slugs on pears, cherries, and quinces. The arsenate of lead also improves the flowing qualities of the dust mixture, there being a tendency for pure sulfur to lump and clog and not flow freely from the duster. In certain experiments of Reddick and Crosby¹¹ this difficulty was overcome by the addition of hydrated lime. But there is some evidence that the lime reduces the fungicidal value of the mixture.¹² Besides, the mixture of sulfur and arsenate of lead appears to have higher adhesive quality than any other sulfur mixture. Experimental work should be continued in the nursery to test different sulfur mixtures in order that the cost of the dust mixture may be reduced as much as possible.

SUMMARY

The results of the experiments performed in 1915 and in 1916 indicate that the application of suitable powdered materials, with air used as a carrier, will control certain leaf diseases of nursery stock as well as does the commonly employed fungicide applied as a spray with water as a carrier.

The dust mixture of ninety parts of finely ground sulfur, practically all of which would pass through a screen of 200 meshes to the inch, and ten parts of equally fine powdered arsenate of lead, controlled the leaf diseases of horse-chestnut, currant, plum, cherry, quince, and rose in the nursery. It is reasonable to believe that the same results might be expected for the control of these diseases under other conditions, such as on cherry, quince, and plum trees in the orchard, or on mature currant bushes.

The dusting method is slightly more expensive, but the applications of the dust mixture can be made in a much shorter time and more thoroughly than can spraying with the usual machines now employed by nurserymen.

Experimental work should be continued, not only to test less expensive dust mixtures in order that the cost of the dust method may be reduced as much as possible, but also to test the value of the dusting method for the control of other leaf diseases found in the nursery.

In conclusion, too much emphasis cannot be laid on the necessity of using in the dust mixture only extremely finely ground materials. The fine materials will stick and adhere to the foliage, while the coarser materials merely roll off the leaves and are of little or no value.

¹¹ Reddick, Donald, and Crosby, C. R. Further experiments in the dusting and spraying of apples. Cornell Univ. Agr. Exp. Sta. Bul. 354:53-96. 1915.

¹² Blodgett, F. M. Further studies on the spread and control of hop mildew. New York (Geneva) Agr. Exp. Sta. Bul. 395:29-80. 1915.

